THE OFFICE OF BEHAVIORAL AND SOCIAL SCIENCES RESEARCH

Healthier Lives through Behavioral and Social Sciences

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The Flavor World of Childhood: Basic Biology and Health Implications




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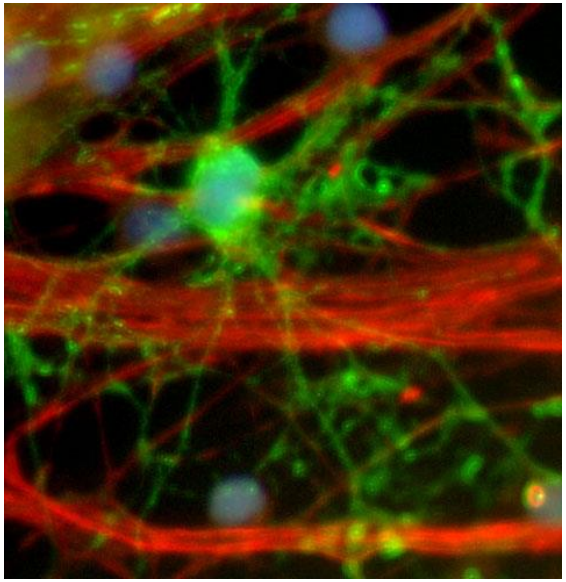
Focus: Normal Development

- Simple question that gets to heart of something quite complex
- How to identify true effects of development;
- Normal function provides insights into vulnerabilities and opportunities.



V. Shukla; 2008 NICHD Image Competition Entry: Section on Nervous System Development and Plasticity (http://retreat.nichd.nih.gov/pastretreats/2008/2008images.html)

Many chronic illnesses that plague modern society derive in large part by poor food choices, dictated by our taste preferences.

- Too much sugar and salt
- Too few vegetables and fruits
- Pattern is apparent in youngest members of our society.

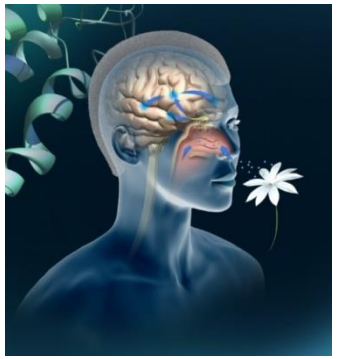
- How can we account for patterns of food choice that seem antithetical to health, and for the difficulties in changing them?

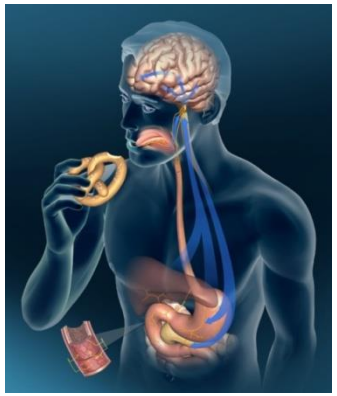
- How can we account for patterns of food choice that seem antithetical to health, and for the difficulties in changing them?

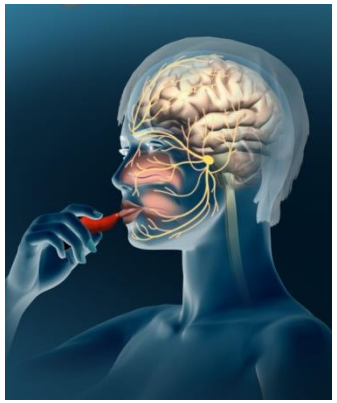
- How do individuals and society manage the rich abundance of food that now characterizes this evolutionary blink of an eye we find ourselves in?

Biological Substrate

Understanding what children are eating and the obesity epidemic must incorporate the biological substrate.







Biology predisposes children to consume diets that may lead to obesity:

- Mismatch of inborn, evolutionarily driven taste preferences and current food environment.

- Humans evolved in *fluctuating* and *uncertain* environments where the primary challenge was to obtain enough nutrients, while avoiding the abundant poisons found in plants.
- In response to challenge, sensory systems evolved to detect and prefer the once *rare* calorie- and sodium-rich foods that taste sweet or salty, while rejecting potentially toxic ones that taste bitter.

Early Humans Loved Fruits

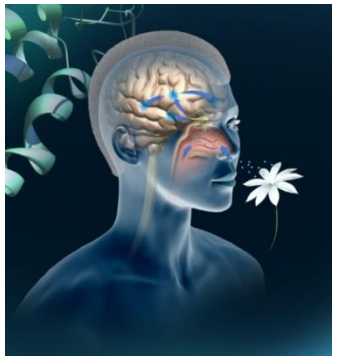
Paranthropus boisei, (Nutcracker Man; large molar teeth and thick, powerful jaw), (M. & L. Leakey, Olduvai Gorge, Tanzania) Ungar et al., 2008
Credit: Nicolle Rager Fuller, NSF

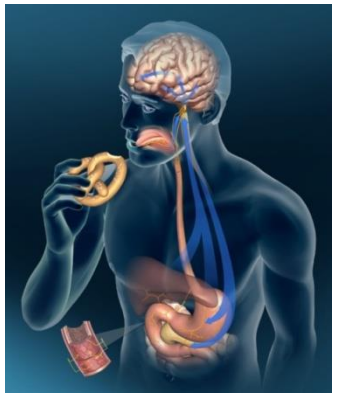
Biology predisposes children to consume diets that may lead to obesity:

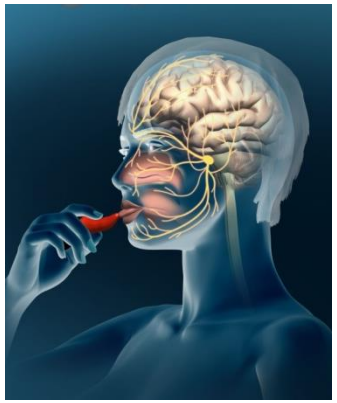
- Mismatch of inborn, evolutionarily driven taste preferences and current food environment;
- Detrimental consequences of <u>not</u> being exposed to flavors of healthy foods early in life.

Flavor Senses

- Central to identifying food and enable us to perceive our chemical world
  - primary signals of food, a basic biological commodity.
- Gatekeepers and warn GI system of incoming nutrients
- Source of extreme pleasure and pain







Senses of Taste and Smell

- Functioning before birth;
- Not miniature adults;
- Inborn responses yet inherent plasticity.

The Taste of Pleasure

Sweet Taste

Infancy

- Within hours of birth, infants exhibit a strong preference for sweet tastes.
- Convergence of findings
  - Intake

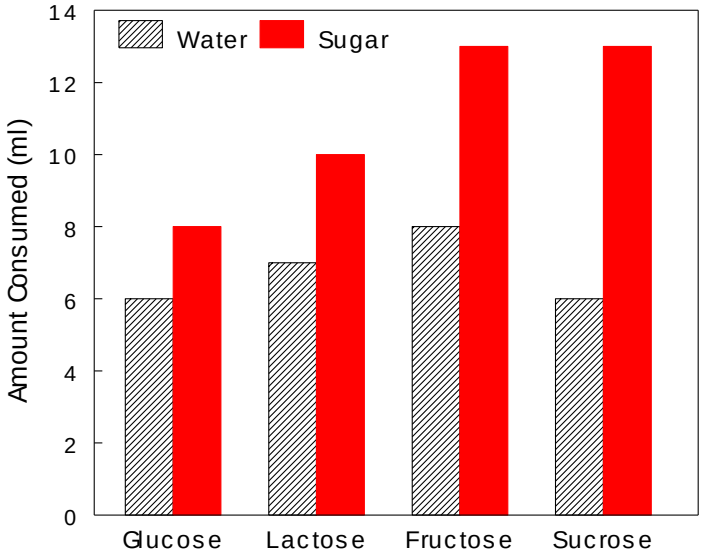
Journal of Comparative and Physiological Psychology
1973, Vol. 84, No. 3, 496-501

TASTE IN ACCEPTANCE OF SUGARS BY HUMAN INFANTS[1]

J. A. DESOR[2]
Monell Chemical Senses Center, University of Pennsylvania

OWEN MALLER AND ROBERT E. TURNER[3]
Monell Chemical Senses Center, University of Pennsylvania, and Veterans Administration Hospital, Philadelphia, Pennsylvania

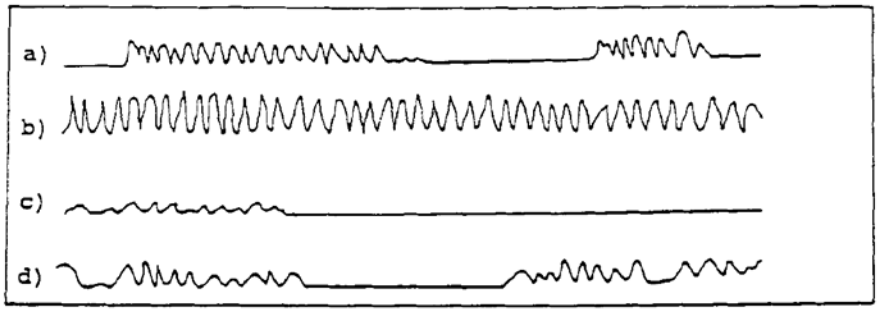
Human infants (1–3 days of age) were offered water and a solution of glucose, fructose, lactose, or sucrose for 3-min. periods. Volumes ingested were measured. Infants discriminated between water and a solution of sugar, demonstrating a distinct preference for the latter. The effectiveness of sugars in evoking ingestion varied with both the compound and the solution concentration.



Infancy

- Within hours of birth, infants exhibit a strong preference for sweet tastes.
- Convergence of findings
  - Intake
  - Suckling patterning

Term (a,b) and Preterm (c,d) Infants



Sucking curves generated by term (a: latex nipple; b:sucrose nipple) and preterm (25-36 wks gestational age) c: latex nipple; d: :sucrose nipple) infant. Maone et al., 1990

Infancy

- Within hours of birth, infants exhibit a strong preference for sweet tastes.
- Convergence of findings
  - Intake
  - Suckling patterning
  - Facial expressions

Steiner et al., *Neurosci Biobehav Rev* 2001

Infancy

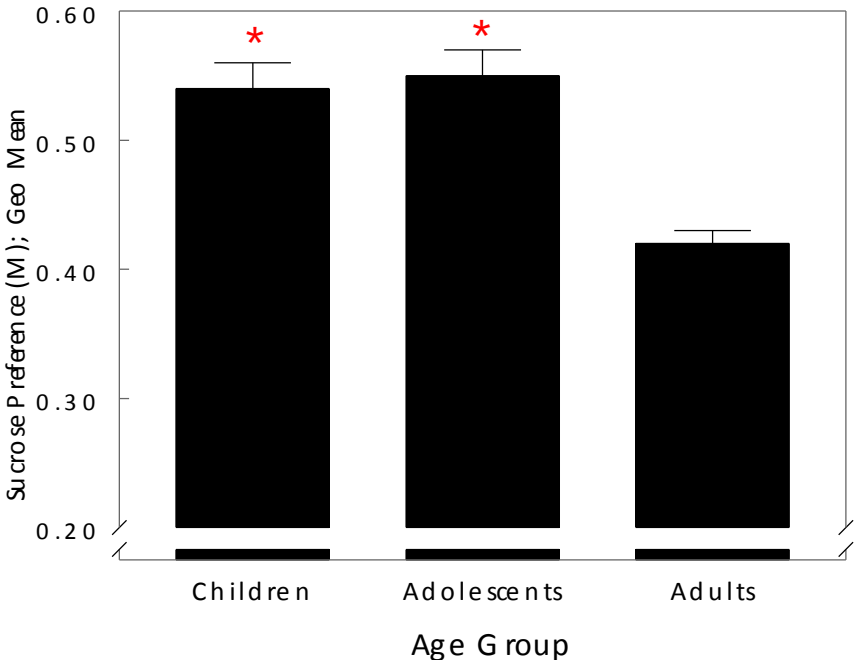
- Within hours of birth, infants exhibit a strong preference for sweet tastes.
- Convergence of findings
  - Intake
  - Suckling patterning
  - Facial expressions
  - Heart rate
  - Blunts expression of pain

Barr et al., 1999

Baby’s first taste of sweet cereal.

Childhood → Adolescence

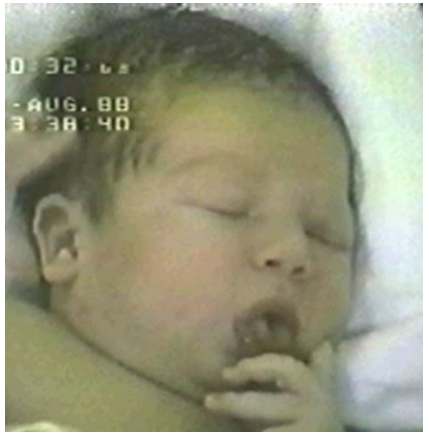
- Most preferred level declines during late adolescence, coincides with cessation of growth.



NIH Toolbox Method
Chemical Senses 36: 345-55 ; 2011

Good News:
Baby born attracted to taste signal for mother's milk

- Children are attracted to taste signal for calories (e.g., fruits) during periods of growth;
- Blunts expression of pain;
- Masks the bad tastes.



Bad News: Children's Vulnerability to Current Food Environment

- Understanding their vulnerability is key to develop evidence-based strategies;
- Why is fruit intake below recommended levels?

Early Humans Loved Fruits

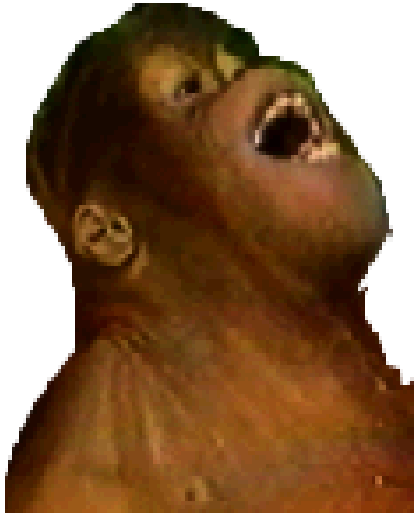
- *Liem Dictum:* specialized morphology can allow for a broader diet wherein a species may actively avoid the very foods to which it is adapted when other, more preferred resources are available;
- Are refined sugars supernormal stimuli?
- Epigenetic changes due to chronic sugar intake early in life?

Paranthropus boisei, (Nutcracker Man; large molar teeth and thick, powerful jaw), (M. & L. Leakey, Olduvai Gorge, Tanzania)
Credit: Nicolle Rager Fuller, NSF
Ungar et al., *PLoS One*, 2008.

The Taste of Poison
Bitter Taste

Bitter Taste

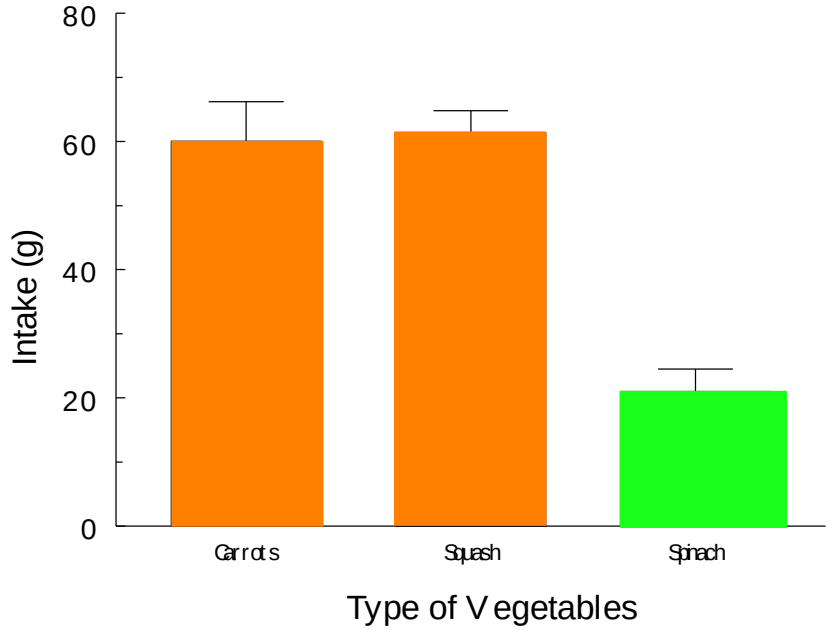
- Rejection protects against harm from potentially toxic agents
  - protects animal from consuming toxic compounds and being poisoned
  - protects plant producing these chemicals from being eaten
- Heightened sensitivity during childhood.



courtesy of Dr. K. Berridge,
University of Michigan
Neurosci Biobehav Rev 2001

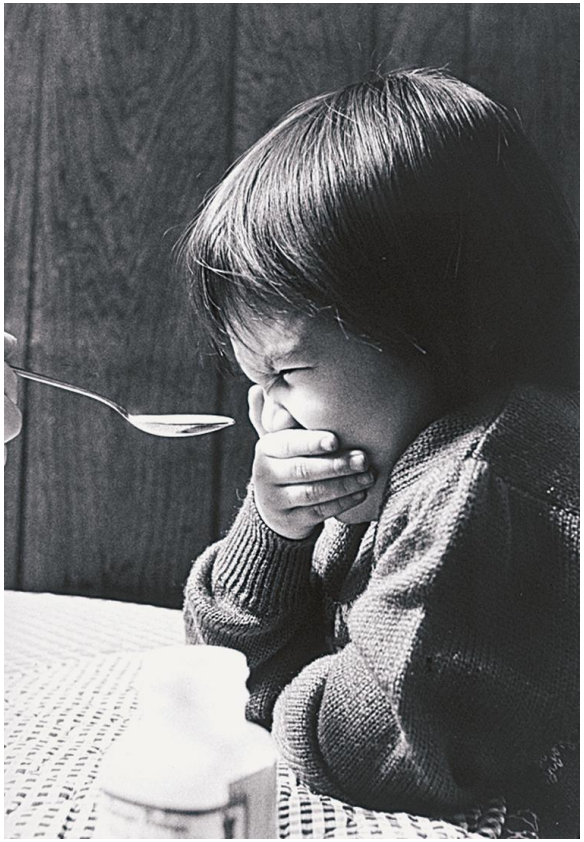
Initial Acceptance of Fruits and Vegetables

- Always will be easier to introduce
  - –fruits than vegetables
  - –orange than green vegetables



Baby’s first taste of broccoli.

Bitter Taste:
Bad Taste of Medicine



It is the same biology!

- We cannot easily change the basic ingrained biology of avoiding bitterness and liking sweets to get children to prefer broccoli to candy.
- If this is the bad news, the good news arises from knowledge gained from our experimental research on how, beginning very early in life, sensory experience can shape and modify flavor and food preferences.

Our biology is <u>not</u> necessarily our destiny!

How do we learn to like fruits and vegetables?

Components: Flavor, Texture, Color

Behavioral and dietary risk factors for non-communicable diseases

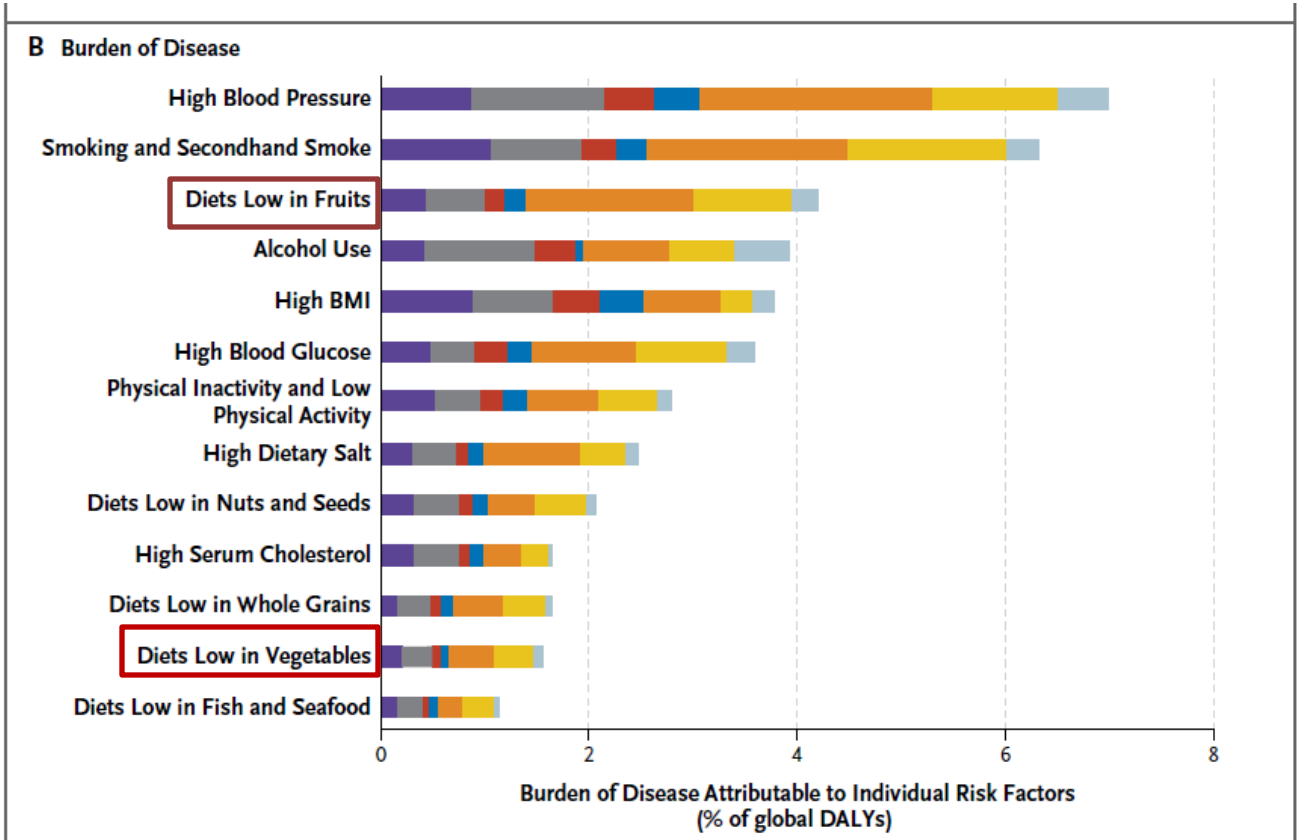
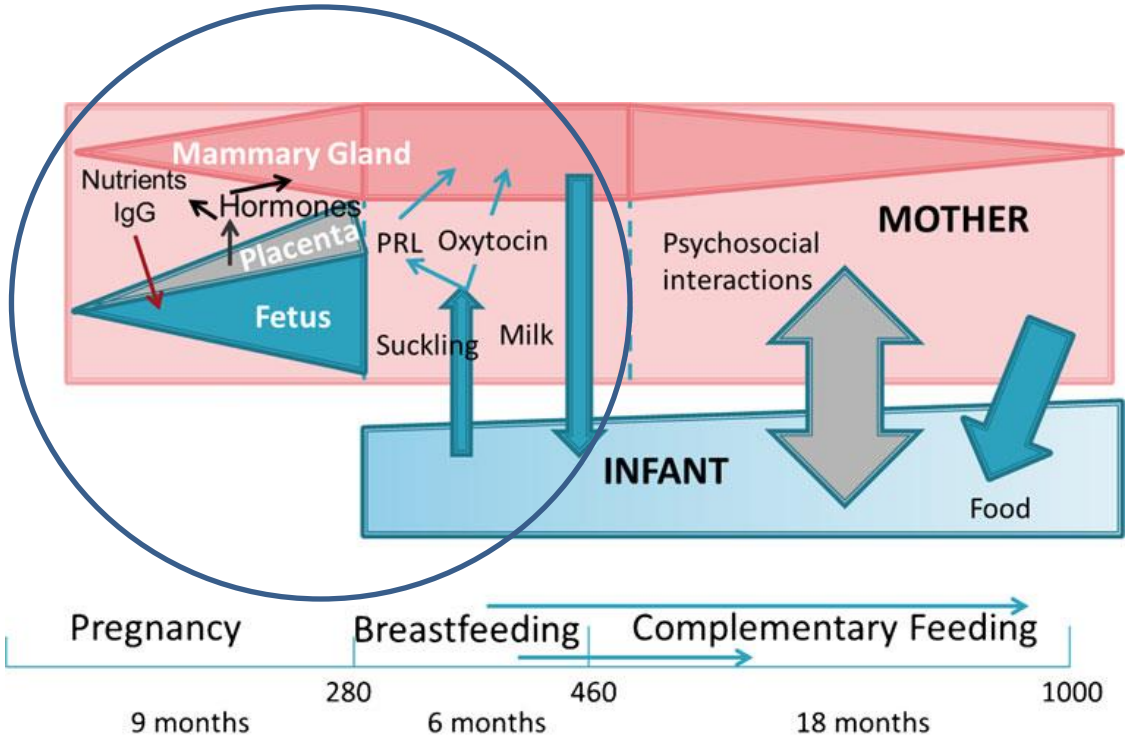


Figure 1. Deaths and Burden of Disease Attributable to Selected Behavioral and Dietary Risk Factors in 2010 and the Metabolic and Physiological Mediators of Their Hazardous Effects.

High-income regions are Australasia, the Asia–Pacific region, North America, and western Europe. The figure shows deaths (Panel A) and disease burden (Panel B) attributable to the total effects of each individual risk factor. There is overlap among the effects of risk factors because of multicausality and because the effects of some risk factors (e.g., physical inactivity) are partly mediated through other risk factors (e.g., high body-mass index [BMI]). Therefore, the deaths and disease burden attributable to individual risk factors cannot simply be added together. DALYs denotes disability-adjusted life-years. Data are from Lim et al.[5]

Ezzati and Riboli. *NEJM* 369: 954-964, 2013

Earliest Information about Nutrition comes from the Mother



Neville et al., 2012

Fundamental Feature of Mammals

- At weaning, young mammals are more accepting of foods that contain flavors previously experienced in amniotic fluid and mother's milk
  - pigs, rabbits, rodents, cows, lambs, dogs, humans, cats, etc.
- By following their mothers, young animals learn
  - What plants to avoid
  - What plants to eat occasionally
  - When plants are at their peak nutritional content
  - What plants to eat when sick

European Rabbit,
Oryctolagus cuniculus

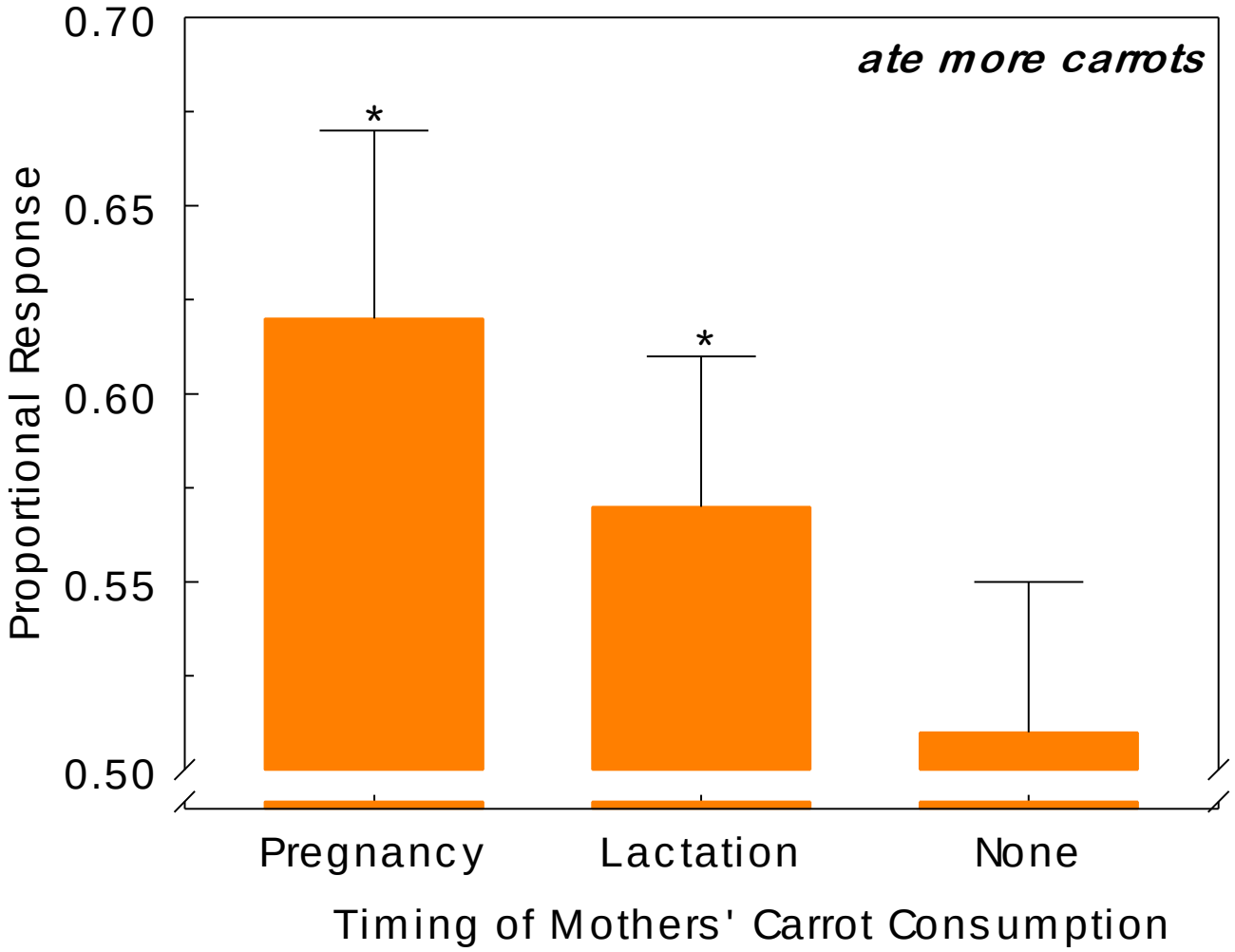
- Variety of flavors are transmitted from mothers' diet to 'first foods'.
- Types of flavors experienced are unique for each infant.
- Flavor memories are formed if mother eats the food.

Experimental Design: Randomized Control Studies

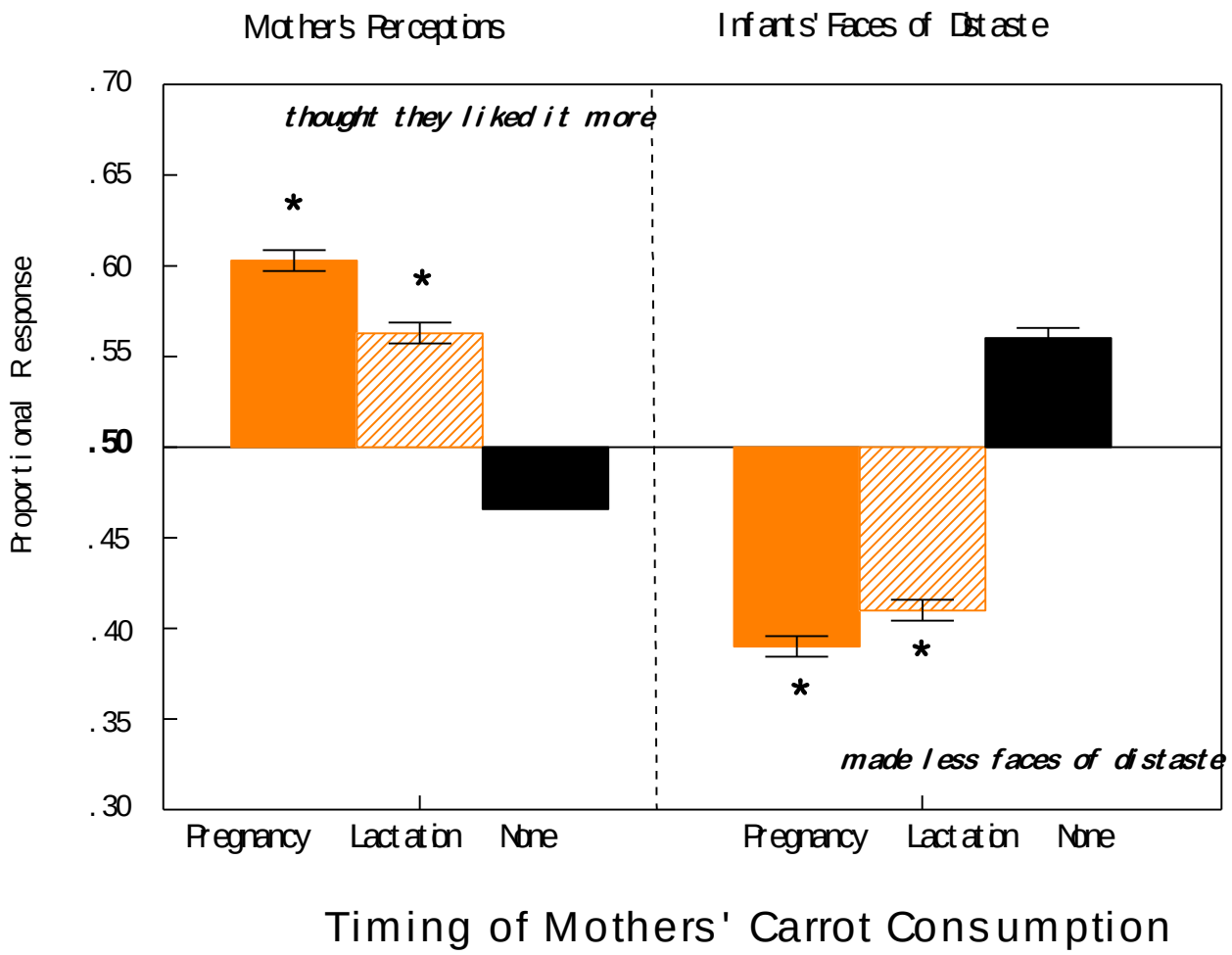
- Pregnant women who intended to breastfeed randomized to 1 of 3 groups.
- Infants tested at weaning
- Variety of outcome measures:
  - Intake and length of feeding
  - facial expressions (FACS)
  - maternal perception of infants' enjoyment of food.

	Pregnancy	Lactation	Test at Weaning
Group CW	CARROT	WATER	Carrot-Flavored vs Plain Cereal
Group WC	WATER	CARROT	Carrot-Flavored vs Plain Cereal
Group WW	WATER	WATER	Carrot-Flavored vs Plain Cereal

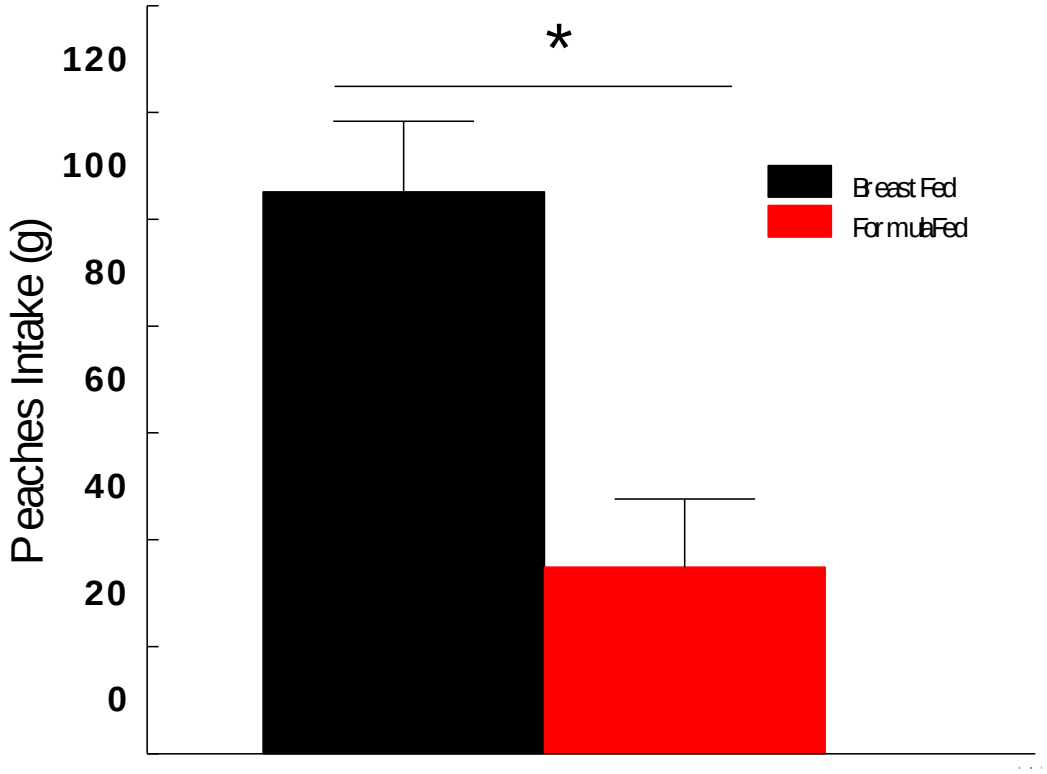
Early experience affected how much they ate.



And how much they liked carrots.



More fruits in mothers' diet, more accepting their infants will be upon first taste of fruits (if breastfed).



This isn’t unique to humans!

Morrill and Dayton, 1978

Aigueperse et al., 2013

“It’s not innate knowledge.
It’s learned and part of their culture.”

F. Provenza, Utah State University

Flavor Bridge

- This pattern makes evolutionary sense because the foods that a mother eats when she is pregnant and nursing are the flavors associated with foods she prefers or, at the very least, with foods she has access to, and hence the foods to which the child will have the earliest exposure.
- First way (not the only way) we learn about flavors of foods.

Learning about Food

- Presence of a food in the environment does not ensure that the animal will learn to eat this particular food.
- Rather, food preferences increase with repeated exposures and variety and are strongly influenced by the conditions in which the exposure occurs.

Both breastfed and formula-fed infants learn!

Target Food	8-10 days later
Peaches	↑ acceptance of peaches ↔ No effect on green bean acceptance
Pears	↑ acceptance of peaches ↔ No effect on green bean acceptance
Variety of Fruits	↑ acceptance of novel fruit ↔ No effect on vegetable acceptance
Carrots	↑ acceptance of carrots
Green Beans	↑ acceptance of green beans
Green Beans and then Peaches	↑ acceptance and liking of green beans
Variety of Vegetables (between and/or within meal)	↑↑ acceptance of target and novel vegetables ↑ acceptance of novel food (chicken)

Collaborators: C. Gerrish, C. Forestell, S. Nicklaus, S. Castor, L. Lukasewycz, G. Beauchamp

How do we learn about foods?

Amniotic Fluid and Milk

Repeated Exposure

Parental Modeling

We build on the familiar flavor, increasing complexity.

Flavor-Nutrient Conditioning

Experience with Flavor Variety

But what about those who are deprived of these experiences?

Peer Modeling

Fruit and Vegetable Intake During Infancy and Early Childhood

AUTHORS: Kirsten A. Grimm, MPH,[a] Sonia A. Kim, PhD,[a] Amy L. Yaroch, PhD,[b] and Kelley S. Scanlon, PhD, RD[a]

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CENTERS FOR DISEASE CONTROL AND PREVENTION

"..infrequent intake of fruits and vegetables during late infancy is associated with infrequent intake of these foods at 6 years of age."

Bottom Line

- Where you start influences where you end up;
- Deprivation model: Most children don't get the experiences to learn to like certain fruits and vegetables
  - Early taste deprivation remodels the central nervous system (Mangold and Hill, 2009)

Hope: Celebrate Parenthood

- There are brief periods in life when old routines fall apart and buying habits are suddenly in flux: one such moment is around the birth of a child;
- Same is true for health behaviors;
- Being pregnant and then a parent is strongest motivator to change or modify behaviors.

C. Duhigg, NY Times 2012

Bottom Line

- Mothers feed their children what they eat;
- Research needed to improve dietary habits of women during pregnancy and postpartum period and to further our understanding of how and when infants learn to like foods.

Child-like Wonder of Science

- Basic research in humans and animal models is the key to continued advances and applications.
- Elegance and simplicity in fundamental principles.
- **Food is more** than source of calories
  - Pleasure, identity, relationship to environment
  - Vulnerability of childhood

Ellen Swallow Richards (1842-1911)

1st American female chemist;
First to apply chemistry to study of nutrition
Founder of Home Economics Movement
1894: started program in Boston high school that led to National School Lunch Program

"Science has to apply its knowledge to (improve) home; for upon the welfare of the home depends the welfare of the commonwealth."

It is truly an exciting time to be a behavioral scientist!

Baby’s first taste of broccoli.

Genotype-Phenotype (*TAS2R38*)

- Children who carried at least one bitter allele (*TAS2R38 gene*) were more sensitive to bitter taste, with changeover during adolescence.
- How does this impact on initial acceptance and learning of fruits and glucosinolate-containing vegetables?
- How does dietary experience relate to allele-specific gene expression and variation in human bitter taste perception?